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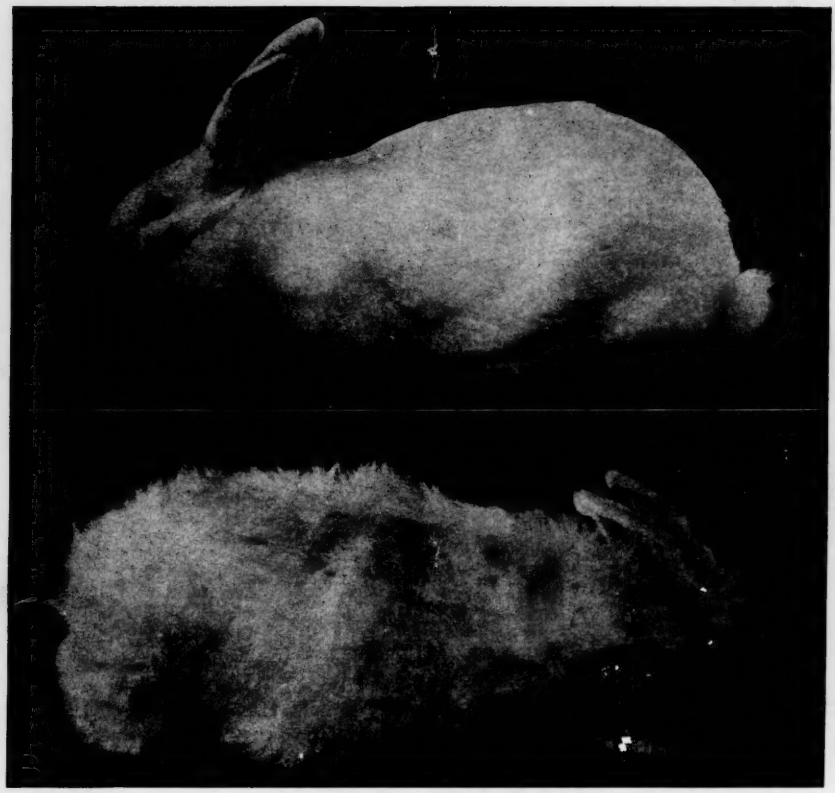

RECESSIVE WOOLLY RABBITS *(B)* A BREEDER'S HEADACHE

(SEE PAGE 183)

Heredity and Environment in Cancer

Thomas Jefferson, Scientific Agriculturist

The Chromosomes of Guayule

VOLUME 35 JUNE, 1944 NUMBER 6

The American Genetic Association

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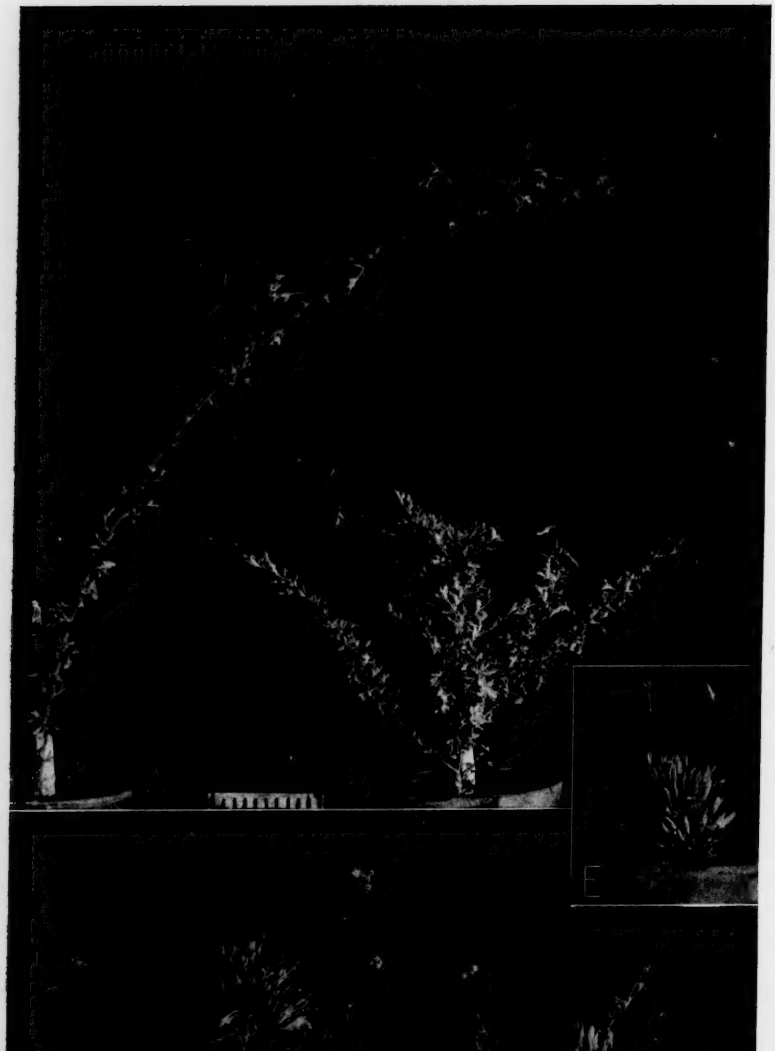

PLANTS OF MARIOLA AND GUAYULE

Figure 1

Mariola is the closest relative of guayule. Six-month-old plants are shown here: *A* is from Alpine, Texas, and has a *2n* chromosome number of 54. *B* is from Superior, Arizona, with a *2n* chromosome count of 72. The three guayule plants (*C-E*) are between one and two years old. All were grown at Berkeley, California. *C* is a plant of strain no. 109, with a *2n* chromosome number of 54. *D* is a plant of strain no. 593, with a *2n* chromosome number of 74. *E* is an autotriploid of strain 593 with a *3n* chromosome number of approximately 111. The scales are graduated in centimeters.

CHROMOSOMAL VARIATION IN GUAYULE AND MARIOLA

G. LEDYARD STEBBINS, JR., AND MASUO KODANI*

ONE important factor which must be considered in any program of improvement by breeding of the rubber-bearing shrub, guayule (*Parthenium argentatum* Gray), is that of whether the various diverse strains now being brought into cultivation have the same or different chromosome numbers. Previous to 1943, the only published work on the cytology of this species was that by various Russian workers,[4,6,7] all of whom stated that in the varieties available to them the haploid number was about $n = 36$. The senior author, however, found deviations from this number among the first three strains examined, so that an investigation of additional strains seemed desirable. In addition, the rather frequent presence of autotriploid plants was noted, and a further study of this interesting phenomenon was considered advisable. Meanwhile, Bergner[3] has recorded somatic numbers ranging from 36 to 39. Finally a comparison between chromosome numbers in *P. argentatum* and its nearest relative, mariola (*P. incanum*), was considered desirable, in view of the fact that hybridization between these two species and subsequent backcrossing almost certainly occurs,[10] and might provide a means of introducing genes for greater hardiness and vigor into *P. argentatum*.

Material and Methods

Some of the strains of *P. argentatum* were secured from the Guayule Research Laboratory, U. S. Dept. of Agriculture, at Salinas, Calif., through the helpful assistance of Dr. LeRoy Powers. One collection of seed (no. A61) was obtained from Zacatecas, Mexico, through Eng. Eduardo Murillo Safa. Another (no. A73) was obtained by Dr. Robert Emerson from Mr. Julius Lopez, and represents the progeny of plants from San Pedro, Coahuila, Mexico. The Texas material was obtained by Dr. Emerson from three different localities. One was above Green Valley, between Casa Piedra and Lagunitas, Presidio County; the second was from Seven-mile Mesa, near Fort Stockton, Pecos County; and the third was collected by A. R. Davis of Marathon, Brewster County, near that town at three different elevations, 2500, 3000, and 3500 ft.

The strains from Salinas are the result of twenty years of selection for high rubber content by Dr. W. B. McCallum; their original wild source is Mexico, but the locality and region are unknown.

Of the four cultures of *P. incanum*, all grown from wild seed, one was collected near Alpine, Texas, by Dr. LeRoy Powers; one near Socorro, N. M., by Dr. A. L. Hershey; the third at Superior, Ariz., by Mr. Fred Gibson, of the Boyce Thompson Southwestern Arboretum. The fourth was obtained from Mr. Lopez, probably of Mexican origin. The authors wish to express their thanks to all of these collectors.

Somatic counts were made from sections of root tips prepared according to the method long in use in this laboratory.[2] Some of the tips were taken from vigorously growing seedlings in six-inch pots, others from cuttings made in the guayule nursery at Manzanar. Both provided metaphase plates adequate for counting, but the chromosomes were best spread in the larger roots from new cuttings. The clumping of the chromosomes found by Dianova, Sosnovetz, and Steschina[6] in their root tip preparations was encountered only in preparations made from old plants or from young

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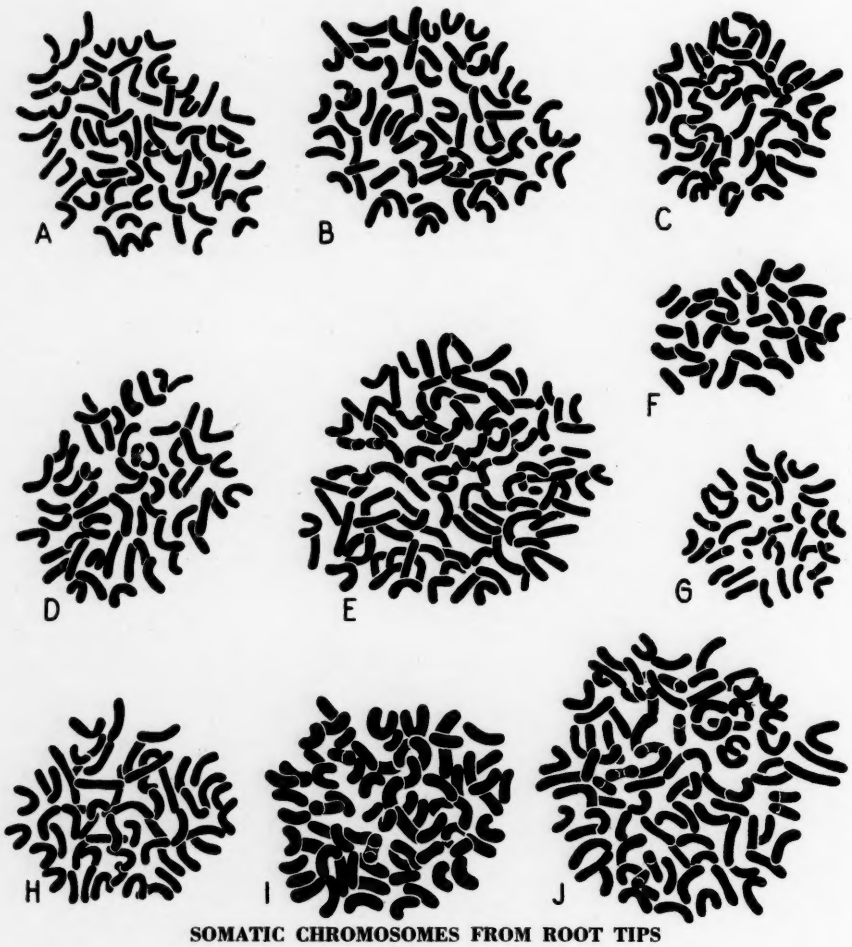


SOMATIC CHROMOSOMES FROM ROOT TIPS

Figure 2

A-G are drawings of guayule chromosomes; *H-J* of mariola chromosomes. *A*—Salinas strain 405, $2n = 72$; *B*—Salinas strain 407, $2n = 74$; *C*—Salinas strain 109, $2n = 54$; *D*—Salinas strain 111, $2n = 58$; *E*—"Autotriploid" from Salinas strain 593, $3n = 111$; *F*—"Haploid" from no. 405, $2n = 36$; *G*—Lopez no. A7308, $2n = 38$. *H*—Mariola from Alpine, Texas, $2n = 54$; *I*—from Superior, Arizona, $2n = 72$; *J*—from Alpine, Texas, $2n = 90$. All figures reproduced $\times 756$.

seedlings or cuttings growing under poor conditions.

Meiosis was studied from aceto-carmine smear preparations of material previously fixed in a 3:1 absolute alcohol acetic acid mixture, and taken from plants growing in the field at Manzanar. All drawings were made under the oil immersion lens, with the aid of a camera lucida, and are reproduced at a magnification of $\times 756$.

Somatic Chromosome Numbers

As can be seen from Table II, most of the strains examined of *P. argentatum*, both from Salinas and from wild

sources have the number reported by the Russian workers, $2n = 72$-74. In the few forms with 72 chromosomes, all of them are about the same size (Figure 2*A*. Most of the strains from Salinas and Texas, however, particularly the widely grown strains nos. 406 and 593, had clearly 74 chromosomes, of which two were definitely smaller than the rest (Figure 2*B*). In a few strains, such as no. 405, some of the plants had 72 and others 74. This difference, as far as could be detected, did not materially affect the external morphology of the plants. In the Texas material examined, the extra pair of small chromosomes was also found. One of the strains from Salinas, no. 109, had consistently the somatic number $2n = 54$ (Figure 2*C*). In this strain, as in those with $2n = 72$, the pair of small chromosomes was not detected. Another number from Salinas, no. 111, contained at least some plants with $2n = 58$ (Figure 2*D*) with at least one small chromosome.

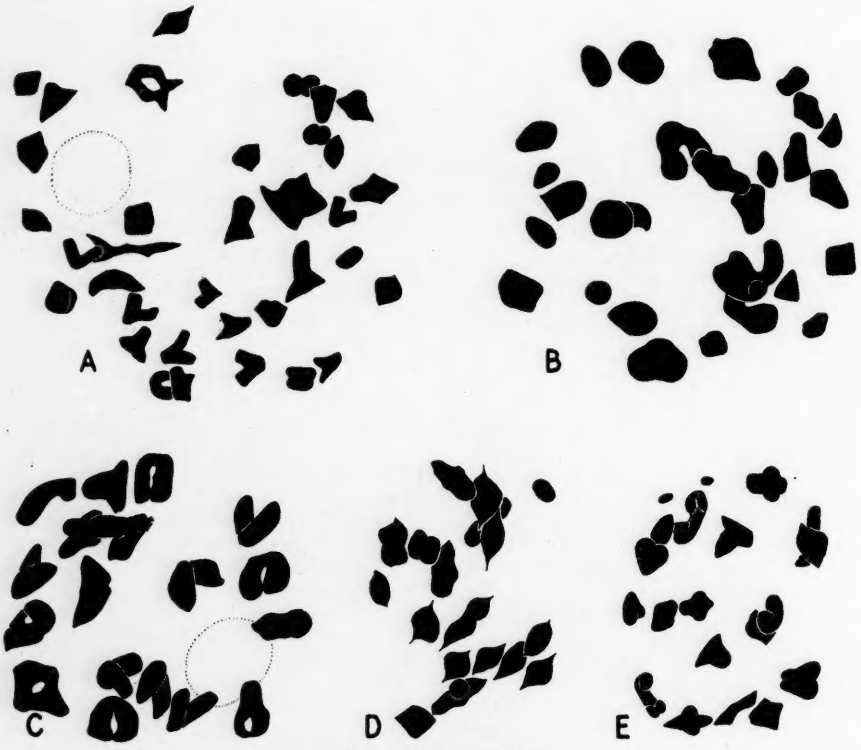
One of the characteristic features of progenies of seedlings from many of the Salinas strains is the presence of relatively small plants with thick, asymmetric leaves (Figure 4*D*). Cytological examination has shown these to have a higher chromosome number than normal plants. Due to the large number of chromosomes, accurate counts were difficult to obtain, but 108-111 chromosomes could be counted with some certainty in a number of metaphases from two different plants (Figure 2*E*), while aceto-carmine smears of shoots from a number of others revealed over 100 chromosomes. It is probable, therefore, that all of the plants with the morphological features shown by those illustrated in Figures 1*E* and 4*D* are autotriploids with reference to their immediate parents. Table I gives the incidence of triploids in nine strains from Salinas and two from Texas. The relative scarcity of triploids in the Texas material is obvious.

The low chromosome number of $2n = 36$ or 38, first reported by Bergner,[3] was found in plants of our collection from three different sources. Of the 20 plants (nos. 6101-6120) grown from the Zacatecas seed, all but one had pollen grains of smaller dimensions than those of typical 72-74 chromosome strains, the grains being regular in size and consistently three-pored. Five of these were found to have 18 bivalents at meiosis, so that it is assumed that all nineteen have 36 somatic chromosomes. The twentieth (no. 6110) had pollen size typical of guayule, and grains with 3-4 pores. Its somatic number was determined as 72-74. One plant, no. 7308, in the Lopez collection and therefore originally from San Pedro, Coahuila, had $2n = 38$ (Figure 2*G*). In it the two small chromosomes characteristic of the 74-chromosome plants are clearly visible. The third instance was a single seedling from a 72-chromosome plant of Salinas strain no. 405, grown at Manzanar. This had 36 somatic chromosomes, and was evidently a haploid produced by the parthenogenetic or pseudogamous development of an egg cell with the reduced chromosome number.

Of the four collections of *P. incanum*, three (those from Arizona, New Mexico, and Mexico (Lopez) had the diploid number $2n = 72$ (Figure 2*I*), which corresponds with the haploid number $n = 36$ reported by Dianova, Sosnovetz, and Steschina[6] for this species. In the collection from Alpine, Texas, two different numbers were found. The majority of the plants had $2n = 54$ (Figure 2*H*), but two plants were found with $2n = 90$ (Figure 2*J*). The low somatic number of 36 ($n = 18$), reported by Botschanszewa,[4] was not found in our material.

Meiosis in *P. Argentatum*

The irregularities of meiosis found by all of the Russian workers[4] were also present in most of the material studied by us. Due to the large number and the crowding of the chromosomes, only a few sporocytes at diakinesis could be fully analyzed. One of the best examples from a 74-chromosome strain, no. 406, is shown in Figure 3*A*. In it trivalents, quadrivalents and univalents as well as bivalents can be seen. The number of multivalents appears to vary from



MEIOTIC CHROMOSOMES

Figure 3

First division of microspore meiosis in guayule. *A*—no. 406, diakinesis, showing two quadrivalents, one trivalent, 31 bivalents, and one univalent. *B*—no. 109, showing three trivalents, 20 bivalents, and five univalents. *C*—no. A6107, showing 18 bivalents. *D*—"Haploid" from no. 405, showing 17 bivalents and two univalents at first metaphase. *E*—no. A7308, showing 18 bivalents and two small univalents. All figures reproduced ×756.

three to six, while most sporocytes have either one or two univalents. In most instances, the univalents occur in the same sporocyte as trivalents, and therefore seem to be the result of failure of pairing in a potential quadrivalent, rather than of lack of homology. As can be seen from Table II, this amount of irregularity is characteristic of the 72- and 74-chromosome Salinas strains studied, but those from Texas were considerably more irregular. The letters *A*, *B*, and *C* designate three different morphological types found in this material.

Plants of strain 109, with 54 chromosomes, and those of no. 111 with 54 or 58 also had a relatively irregular meiosis. The number of multivalents at diakinesis was approximately the same (Figure 3*B*), but the number of univalents was definitely larger, varying mostly from four to six. These irregularities included also a greater amount of lagging of chromosomes at first and second anaphase, and a higher proportion of tetrads with extra nuclei (Table II).

The "autotriploid" plant studied which was the F_1 offspring of a plant of Salinas strain no. 428 growing at Manzanar, had a meiosis somewhat more irregular than its 74-chromosome progenitor, but no more so than 74-chromosome plants

from other sources. No diakinesis cells clear enough for analysis were found, but evidence of multivalent configurations was plentiful, and associations of as many as six chromosomes are almost certainly present.

Meiosis in the 36- and 38-chromosome plants was remarkably regular. In 13 out of 14 sporocytes at diakinesis of no. 6107, 18 bivalents were observed (Figure 3*C*); in the other a single pair of univalents occurred. In the 36-chromosome haploid from no. 405, most of the few diakinesis and metaphase sporocytes observed showed one pair of univalents (Figure 3*D*), while in the 38-chromosome plant, no. 7308 (Figure 3*E*), the two small chromosomes were usually loosely paired or unpaired, while occasionally a pair of normal sized univalents was found. In all of these plants the percentage of sporocytes with lagging chromosomes and of abnormal tetrads was remarkably low (Table II).

The amount of irregularity in the later stages of meiosis agrees in general with what would be expected from the behavior of the chromosomes at diakinesis and first metaphase. Notable exceptions are, however, found in the high frequency in certain strains of triads, and therefore of giant pollen grains with the unreduced chromosome number (Table III). This is most conspicuous in Salinas strain no. 428, which also produced the highest percentage of triploid progeny, but in the other 74-chromosome Salinas strain studied, no. 406, the frequency is also high. The formation of triads is evidently due to the occurrence in these strains of the fusion of adjacent groups of chromosomes at the second meiotic anaphase, as reported by Stebbins and Jenkins[12] in *Crepis*.

Pollen and Seed Fertility

As can be seen from Table III, pollen fertility is in general correlated with the percentage of normal meiotic divisions, as shown in Table II. There is, however, a slight exception to this correlation. In the two 72-74 chromosome strains from Salinas, nos. 406 and 428, pollen fertility was rather low compared to the percentage of normal first meiotic metaphases whereas in the Texas strains with the same chromosome number, as well as the 54 and 58 chromosome strains, nos. 109 and 111, the percentage of good appearing pollen grains was greater than that of normal first metaphases. The significance of this difference, if any, must await further information. A more striking situation is the very low pollen fertility of the 36-chromosome haploid from no. 405, as contrasted with the high fertility of the naturally occurring plants with the same chromosome number. Such observations of meiosis as were made on this plant, although too few to enable them to be entered in Table II, did not indicate a degree of meiotic irregularity sufficient to explain this sterility.

The occurrence of giant pollen grains might be expected from the presence of triads, and therefore of unreduced gametes, as indicated in Table II. These grains, therefore, undoubtedly contain the unreduced chromosome number. Their frequency in each strain is, as would be expected, about one-third the frequency of triads in the same strain, as can be seen by comparing the figures in Table III with those in Table II. Their very high frequency in strain no. 428 is noteworthy in view of the high percentage of triploids among the offspring of this strain, and will be discussed below.

The percentage of fertile seed formed at Manzanar was in all but one of the strains about one-half of what would be expected on the basis of pollen fertility, and the two series of figures are fairly well correlated (Table III). The exceptional strain was no. A7301, from the Lopez collection, in which the percentage of seed set was conspicuously higher than in any other strain, in spite of the fact that pollen fertility was relatively low, and meiosis was more irregular than in any other strain investigated. This discrepancy could be best accounted for on the assumption that some type of apomixis is prevalent in this strain. Although the various Russian authors have consistently denied the presence of apo-

mixis in guayule,[4,6,7] recent unpublished studies by Dr. Katherine Esau indicate that a greater or lesser percentage of apomictic reproduction does occur in this species.

Discussion

The most remarkable and unusual feature of the cytogenetics of guayule is the very high percentage in many progenies of offspring that are autotriploid with respect to their immediate parents. These parents, of course, must themselves be considered polyploids. Those with 72-74 chromosomes are tetraploid with reference to the lowest chromosome number, $n = 18$, yet found in guayule or its relatives, but may actually be octoploids, since the whole series of numbers reported in *P. argentatum* and *P. incanum* suggests a basic haploid number of $\chi = 9$. The "autotriploids" with 108-111 chromosomes, therefore, are actually either hexaploid or 12-ploid.

The only record known to the writers of a similar regular occurrence of autotriploids is that of Navashin[9] in *Crepis capillaris*. The percentage of triploids in *Crepis*, however, is much lower than that in some of the guayule strains investigated. In both genera there is little doubt that these plants originate from the fusion of a normal haploid gamete with one containing the unreduced number of chromosomes. In guayule there is as yet no decisive evidence to indicate whether the unreduced gamete which functions is an egg cell or a pollen grain or whether it may be either. The association in strain 428 between a high frequency of unreduced pollen grains and a high percentage of triploid offspring (cf. Tables I and III) suggests that in this strain the giant pollen grains are functioning, but in other strains the evidence suggests the reverse situation. In no. 406, for instance, the percentage of triploids is, as in no. 428, higher than that of unreduced pollen grains, while in the Texas strains it is much lower.

The incidence of triploidy in the progeny is a cytogenetic characteristic of guayule strains which is of considerable economic significance. The triploids are, because of their small size and sterility, very undesirable plants, so that any strain which produces a high percentage of such offspring is itself undesirable, even though the normal offspring may be vigorous and high in rubber content. The dwarf size and abnormality of these plants is similar to that of high polyploids in *Nicotiana*,[5] and, along with the distribution of chromosome numbers in nature, indicates that with the genotype of *P. argentatum* and *P. incanum* the optimum conditions for vegetative vigor are reached at the 72-74 chromosome level.

The evidence now at hand permits the formulation of a working hypothesis as to the nature and origin of polyploidy in *Parthenium argentatum*. When compared with typical 72-74 chromosome strains, the types with 54 and 36 chromosomes have a laxer growth, longer branches, and more elongate, long-petioled leaves of a thinner texture (Figures 1*C-E*, 4*D*). The omission of a 36-chromosome plant from Figure 1 is due to the fact that the photographs were taken at Berkeley, while the 36-chromosome plants were grown only at Manzanar. The difference between the 54 and 72 chromosome forms of mariola studied was similar (Figure 1*A-B*); the plant with 90 chromosomes was considerably smaller, but was not illustrated because it was not growing under comparable conditions. All of these morphological features are typical of the differences between autotetraploids and their diploid progenitors.[11] In inflorescence, flower and achene characters the 36- and 38-chromosome plants vary greatly among themselves, and no floral characteristics are found in the 54- and 72-74 chromosome plants which cannot be duplicated in some plant with 36 or 38 chromosomes. All of this evidence points to the autopolyploid origin of at least the most typical 72-74 chromosome strains. The evidence from meiosis in general supports this hypothesis, since no multivalents have ever been found in our 36- or 38-chromosome plants, while these occur regularly in the strains with higher numbers. Furthermore, the former have

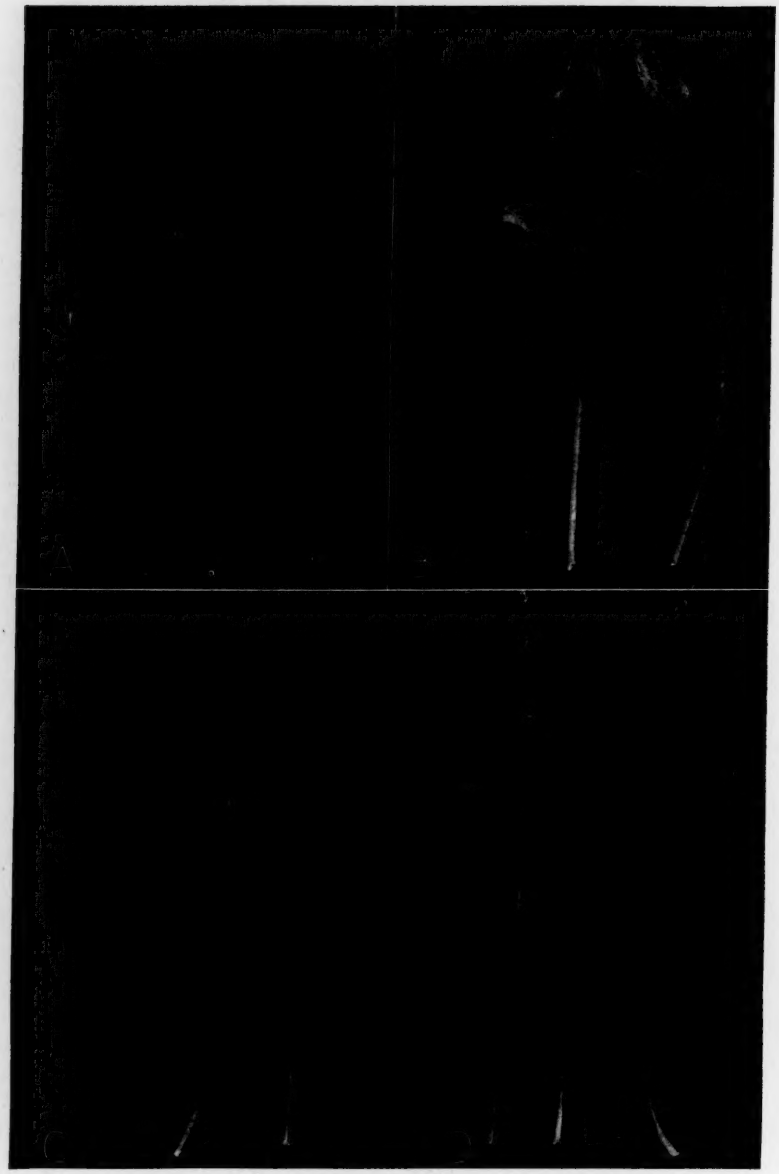
comparatively regular meiosis, while the latter have the meiotic irregularities characteristic of autotetraploids.

Three facts speak against the hypothesis of autopolyploidy. In the first place, the somatic number 72 is relatively uncommon, while 76, the number which would result from doubling in a strain with 38 chromosomes, is unknown. Most of the strains of guayule, with their 74 chromosomes, appear to be derived from hybrids between 36- and 38-chromosome types, with subsequent doubling of the chromosome number. Since the only 38-chromosome plant known, no. A7308, has the pair of small chromosomes characteristic of the 74-chromosome strains, these latter could be produced by doubling in hybrids between plants similar to A7308 and those of the A61 series. The only conspicuous difference between these two is the comparatively small size of the involucres and achenes in no. A7308. The latter are only 1.5 mm long, as compared with 2.3-2.7 mm in the A61 series. On morphological grounds, there is no reason to believe that the two should be placed in different species, so that the 37-chromosome hybrid between them would be an inter-racial rather than an interspecific hybrid, and the 74-chromosome polyploid derived from such a hybrid would therefore still be considered an autopolyploid. Genetic proof of this supposition could, of course, be obtained.

More serious evidence against the hypothesis of autopolyploidy is the sterility of the haploids and triploids derived from 72- and 74-chromosome strains. If these latter were strict autopolyploids, the haploids from them should, like the naturally occurring 36-38 chromosome forms, have regular meiosis and be fertile. The single haploid obtained, however, had a somewhat irregular meiosis and very low fertility, as would characterize the haploid from a partial allopolyploid. Nevertheless, the amount of pairing was sufficiently great to indicate a high degree of homology between the four sets of its 72-chromosome progenitor. The sterility of the "autotriploids," moreover, would hardly be expected if they were actually autohexaploids, although in their case the general lack of vigor of the plants could be a contributing factor. This whole situation could be explained if the 72- and 74-chromosome forms are modified autotetraploids, in which considerable rearrangement of chromosomal segments has occurred since they originated. In view of their irregularities of meiosis and their wide geographic range, which bespeaks their antiquity, such modification is not unexpected.

Another type of modification of these tetraploids very likely consists of hybridization of *P. incanum*[10] and subsequent backcrossing; in other words of introgressive hybridization with mariola.[1] Morphologically the greatest amount of introgression of any form included in this study is in no. A7301, a specimen of which was identified by Dr. Rollins as the "intermediate" type described by him.[10] This corresponds with the mariola-like type of guayule first described by Lloyd,[8] and given the specific name *P. lloydii* Bartlett. Its high degree of meiotic irregularity, therefore, is very likely due to the presence of some chromosomes or chromosomal segments from *P. incanum*. This is apparently true to a lesser degree in the Texas material, particularly type A. The Salinas strains nos. 405, 406, 428, and 593 do not give evidence of such introgression.

The cytogenetic structure of *P. argentatum* may therefore be summarized as follows. There is an original group of 36-chromosome races, apparently confined to the southwestern part of the range of the species, from central and western Zacatecas (see above) to southern and eastern Durango,[3] and perhaps farther to the northwest. From this type has originated, presumably through reduplication of part of a chromosome, the 38-chromosome type. The range of this type is unknown, but most probably is adjacent to or within the area of the 36-chromosome plants, since most of the early collections of guayule were apparently made in northern Zacatecas and southern Coahuila.[8] From the 36-chromosome plants, autopolyploidy produced



GUAYULE LEAVES

Figure 4

Leaves are shown from four plants from one to two years old. *A* is of a plant from Zacatecas (A6107), with a $2n$ chromosome number of 36. *B* shows leaves from a plant of strain no. 109, with a $2n$ chromosome number of 54. *C* and *D* are from plants of strain 593; *C* being diploid ($2n = 74$), and *D* being an autotriploid ($3n =$ approximately 111). Dwarf stature and abnormally shaped leaves characterize the autotriploid.

those with 72 chromosomes, while those with $2n = 74$ resulted either from chromosome doubling in hybrids between 36- and 38-chromosome plants, or from fragmentation and reduplication in 72-chromosome plants. The 72- and 74-chromosome types spread northward and eastward, and during this spread underwent some chromosomal rearrangement, while some of their descendants acquired genes from *P. incanum* through introgressive hybridization. This latter process has undoubtedly contributed much to the variability and extension of range of guayule, although the extent of this influence cannot at present be estimated. The 54-chromosome types were derived either as autotriploids directly from those with 36 chromosomes, or through hybridization between 36- and 72-chromosome plants. The 58-chromosome plants of no. 111 are the result either of segregation from hybrids between 54- and 72-chromosome types or of autotriploidy in those with 38 chromosomes, followed by additional reduplication.

No conclusive data are yet available on the relation between chromosome number and rubber content. Preliminary analyses by Dr. James Bonner, of the California Institute of Technology, using twigs of one season's growth from one-half to one year old shrubs suggest that the highest rubber content is found in certain of the 74-chromosome strains, including some from Texas as well as from Mexico, that the 36-chromosome plants are lowest in rubber content, and that those with 54-58 and with 108-111 chromosomes are intermediate. These data, however, must be considered provisional until analyses have been made of older shrubs.

TABLE I. Incidence of Triploids in *P. argentatum*.

Strain	Chromosome number	Total No. of Plants	Number of Triploids	Per cent Triploids
111	58	139	2	1.5
49	72-74	12	1	8.3
405	72-74	109	18	16
406	74	94	15	16
407	72-74	13	1	8
420	72-74	58	8	13
427	72-74	29	5	17
428	72-74	53	26	49
593	74	957	60	5.9
Texas A	74	443	4	0.9
Texas B	74	717	1	0.14

Summary

1. The somatic chromosome numbers 36, 38, 54, 58, 72, 74, and 108-111

Table II. Meiotic Irregularity

Strain	First Metaphase: Chromosome number	First Metaphase: % Normal	First Metaphase: % with lagging	First Metaphase: Max. no. of lagging chro.	Tetrads: % Normal	Tetrads: % with micronuclei or microcyte	Tetrads: % Triads
P. argentatum							
406	74	89	11	4	79	10	11
428 (2*n*)	72	95	5	1	75	0	25
428 (3*n*)	108	46	54	3	95	1	4
A7301	72-74	18	72	7	33	53	14
Texas A (Ft. Stock.)	74	52	48	4	59	34	7
Texas B (Ft. Stock.)	74	78	22	2	87.3	2.5	10.2
Texas C (Marathon)	74	72	28	2	86	5	9
109	54	59	41	6	62	30	8
111	58	48	52	4	62	36.6	1.4
A6104	36	95	5	4	95	1	4
A6107	36	95	5	2	94	0	6
A7308	38	96	4	4	92	2	6
P. incanum							
Mexico (Lopez)	72	72	28	3	73	10	17
Socorro, New Mexico)	72	47	53	5	85.4	4.9	9.7
Alpine, Texas	54	64	36	4	82	15	3

TABLE III. Pollen Fertility and Seed Set

Strain	Pollen in Percentage: Normal Size Good	Normal Size Bad	Giant	Small	Per cent Seed Set
P. argentatum					
406	76.7	18	4	1.3	34
428 (2*n*)	85.5	6.2	8.3	0	45
428 (3n)	76.6	20.8	1.3	1.3	2.7
A7301	64.4	22	4	9.6	62
Texas A	64.8	23	2.2	10	33
Texas B	86.1	10	3.4	0.5	47
Texas C	69.9	25.6	3.1	1.4	40
109	75.2	15	2.5	7.3	38
111	74.06	22	0.44	3.5	31
A6104	97.8	0.4	1.4	0.4	46
A6107	92.3	5.4	2.3	0	48
A7308	85.7	12	2.1	0.2	45
405 (1*n*)	7.7	92	0.3	0	0
P. incanum					
Mexico (Lopez)	79	13	5.5	2.5	33
Socorro, New Mexico	72.5	24	2.7	0.8	50
Alpine, Texas	59.8	38	1	1.2	26

are reported for guayule, *Parthenium argentatum*. The plants with 38 and 74 have a single pair of relatively small chromosomes.

2. The numbers reported for mariola, *P. incanum*, are $2n = 54$, 72, and 90. The entire series found in the two species indicates that they are a polyploid series on the basic number $x = 9$.

3. The plants with 108-111 chromosomes appear in progenies of those with $2n = 72$ or 74, and are therefore autotriploid with respect to their immediate parents. Morphologically, they are of a dwarf stature and have abnormally shaped leaves.

4. The plants with 36 chromosomes are of two types. The first was grown from wild seed collected near Zacatecas, Mexico, the second was a single plant among a progeny from a 72-chromosome strain, and was therefore presumably a haploid derived by parthenogenesis or pseudogamy.

5. Meiosis in plants with 54, 72, and 74 chromosomes shows the irregularities previously reported for guayule, while that in 36 and 38 chromosome plants from wild seed is more regular. Pollen and seed fertility are fairly well correlated with the degree of meiotic irregularity, except that seed fertility is about one-half what would be expected on the basis of pollen fertility. The single plant which was exceptional in these relationships corresponded morphologically to types intermediate between *P. argentatum* and *P. incanum*. Both the autotriploids and the haploid derived from 72- and 74-chromosome parents were highly sterile.

6. The strains of guayule with 54, 72, and 74 chromosomes are believed to be of autopolyploid origin, but have probably undergone secondary modification through rearrangement of chromosome segments and introgressive hybridization with mariola.

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Pleiotropy in Petunia

Crosses of two petunia varieties, Flaming Velvet × Hollywood Star, show dominance of the leaf types and corolla form of the Flaming Velvet parent, according to John Walker (*Scientific Agriculture* 24:251-258). In the F_1 and backcross progeny these corolla and leaf characters were always associated in Walker's material. Either there is very close linkage or the same gene is involved in the expression of both characters.

THOMAS JEFFERSON: PIONEER IN GENETIC SCIENCE

DeWitt C. Wing

JEFFERSON'S empirical method was expressed in his statement that "a patient pursuit of facts, and cautious combination and comparison of them, is the drudgery to which man is subjected by his Maker, if he wishes to attain to sure knowledge." Jefferson, therefore, was suspicious of dogmas, absolutes, authorities and *a priori* ideas in every field. A century and a half ago he was deeply interested in heredity as a subject of prime importance.

It is a tenable assumption that in England and France, Jefferson became interested in the improvement of sheep, cattle and other farm livestock that had been effected through selective inbreeding and outcrossing, leading to the establishment of pedigree herds and flocks which supplied seedstock at high prices to English and French farmers and eventually to farmers in the United States, Canada and Argentina. The England of that time was on the eve of that Golden Age of cattle improvement, which began with Robert Bakewell of Dishley about 1745, and culminated later in the work of such great breeders as the Collings, Bates, Crookshank and others. So enthusiastic a farmer as Jefferson must have seen and sensed the importance of these developments.

Jefferson, who was born on April 13, 1743,—two centuries ago—was a promoter of breeding better and more efficient livestock. After finishing his second term as President of the United States, he wrote a letter to President James Madison, proposing a plan for distributing Merino sheep and for conducting purebred sire demonstrations with the rams. Jefferson also proposed a system of priorities, pioneering in this method of dividing limited supplies among many needs. Referring to some Merino sheep that he and President Madison had acquired, Jefferson said, in part, writing from his home, Monticello, in Virginia:

> No sentiment is more acknowledged in the family of agriculturists than that the few who can afford it should . . . give benefits freely to the many of more restricted circumstances. . . . I will throw out a first idea. Give all the full-blooded (Merino) males we can raise to the different counties of our State, one to each as fast as we can furnish them. And as there must be some rule of priority for the distribution, let us begin with our own counties, which are contiguous and nearly central to the State, and proceed, circle after circle, till we have given a ram to every county. . . . We shall retain ourselves all the full-blooded ewes, that they may enable us the sooner to furnish a male to every county. When all shall have been provided with rams, we may, in a year or two more, be in condition to give an ewe also to every county, if it be thought necessary. . . . Our whole State may thus, from this small stock, so dispersed, be filled in a very few years with this valuable race.

Jefferson proposed also a supplementary plan for the sale of certain additional animals and their wool to help finance the undertaking. Whether from the stimulus of his plan or because of the State's natural resources, it is noteworthy that Virginia has been for many years and is now one of the leading sheep and wool-producing States of the eastern seaboard.

Jefferson's influence on American farming through his lifelong interest in scientific agriculture was portrayed in an exhibit opening Sunday, April 9, 1944, in the patio of the Administration Building of the U. S. Department of Agriculture. The exhibit continued through April 23. As a tribute to Jefferson, the agriculturist, under the direction of the National Agricultural Jefferson Bicentenary Committee, the exhibit brought together many interesting facts connected with his devotion to science, geography and farming, his political philosophies, and his love of freedom.

"Thomas Jefferson," says Secretary Claude R. Wickard, chairman of the committee authorized by Congress, "was

not only the architect of the democratic way of life which we are defending in this war. He was also the primogenitor of the kind of scientific agriculture employed by us today — an agriculture which enables our 6 million farmers and 20 million Victory gardeners to produce the food that fights for freedom in 1944." The exhibit included a reproduction of the wooden moldboard for a plow, which was the last improvement on the woden plows of Jefferson's time and the forerunner of the modern steel plows. One panel in the exhibit was devoted to illustrations of Jefferson's method of soil conservation through horizontal plowing. Harrow points and bits found at Shadwell, Jefferson's birthplace in Albemarle County, were also on display.

The Louisiana Purchase, obtained from France in 1803, during Jefferson's first administration as President, included what is now the center of agricultural America. The Purchase illustrates Jefferson's grasp of the importance of soil and geography. The exhibit appropriately included a number of maps of Jefferson's time and emphasized the importance of the Louisiana Purchase in our food economy today. The exhibit illustrated many of Jefferson's practical contributions to agriculture. Outstanding among these were his continuous search for labor-saving devices on the farm; crop rotation; introduction of new and experimental plants from abroad, and the breeding of Merino sheep.

Also notable among Jefferson's contributions were his leadership in education and proposals made by him that later led to the establishment of the cooperative United States Department of Agriculture-State agricultural college extension service with county agents and 4-H Clubs in more than 3,000 agricultural counties. The Jefferson exhibit in the Department was a part of the observance of the Jefferson Bicentenary. On Jefferson's birthday, April 13, a group of agricultural officials and members of the Bicentenary Committee, headed by Secretary Wickard, journeyed to Jefferson's home at Monticello, where ceremonies marking the event were held.

Jefferson the Plantsman

"As a result of experimentation, Jefferson domesticated many trees and shrubs native and foreign, that were able to stand the Virginia winters. He collected these trees and shrubs from all parts of the world in order to plant them at Monticello. Among the trees with which Jefferson experimented were three very rare trees for this area—the silk tree, the paper mulberry tree and the bread tree. He tried almost every species of valuable nut, vegetable, grain, bulb, shrub, tree, and grass the world knew at that time. In the year 1812 according to his Garden Book, thirty-two vegetables were cultivated at Monticello. In addition to these vegetables, twenty-two crops were raised, including turnips, vetch, buckwheat, potatoes, wheat, rye, oats, barley, Indian corn, peas, clover, fodder, cotton, artichokes, straw, lucerne, succory, pumpkins, hay, carrots, hemp and flax.

"Even back in that time the farmers' crops were often ruined or blighted by pests. Most of the agriculturalists, being deeply religious, accepted their fate as an "Act of God." Not so Jefferson however. He immediately began to experiment both to produce a crop hardy enough to withstand the attack of the pests as well as to find a means of ridding the attacked crop of them. The Hessian fly was a particular menace to the growing of wheat. He tried many experiments and finally found that the burning of the stubble was an effective way of destroying this pest. This method is still in common practice. He also advocated the sowing of the wheat late enough to escape the fly."—JAMES E. WARD, Clemsen Agricultural College, at Jefferson Memorial Ceremonies, April 13, 1944.

RACE, STOCK AND ENVIRONMENT IN HUMAN CANCER

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CANCER statistics have persistently shown differences in mortality between whites and colored, South and North. The differences are subject to various interpretations. Even less is known about cancer incidence* and morbidity (called also prevalence†) than is known about mortality. Do Negroes have an equal or a smaller cancer incidence and mortality, as compared with whites? Does our southern white population really have a low cancer mortality? And, if so, is it due to a low cancer incidence, or is the mortality low in spite of an undiminished or even an increased incidence? Are inherited qualities or environmental influences, or both, responsible for the variations? Official statistics are of no avail in answering these questions. Special surveys are necessary.

The U. S. Public Health Service has been conducting one-year surveys in ten areas; four in the South, four in the North and two in the West. Together, the ten areas comprise a population of thirteen million. Five areas have been surveyed in 1937, four in 1938 and one in 1939. Reports on the surveys which are supposed to throw light on problems like those indicated above, were published in 1939-1942. Recently, H. F. Dorn[2] summarized all the findings.

The exact number of inhabitants and their biological composition in the ten areas under study were unknown until a short while ago, and the reports gave us only estimates of crude rates. In his recent report, however, Dorn related the collected material to the census data of 1940, the assumption having been made that the structure of the samples (race, sex, age) in the study-year was equal to that of the average of large cities (100,000+..) of the country in 1940. The standardized rates (Dorn) are considered a fair basis for conclusions concerning the three regions, that is South, North and West and the whole country as well.

A basic difficulty with the study is that in dealing with a chronic disease such as cancer, isolated *one*-year surveys on incidence and on morbidity (prevalence) are far too short-termed to yield reliable results. A glance through the statistics on cancer reported in New York State illustrates the great changes from year to year.[3] Some of the irregularities in Dorn's tables (see Table 5, p. 75, colored males, South) are to be explained in this way. Had the survey been extended over a period of five years, rates and quantitative relations between the rates would have been quite different, and so also the opinions voiced as conclusions. But, even then, for a number of reasons, the results would have been dubious.

The fullest cooperation of physicians and hospitals does not prevent a great number of cancer cases from remaining undiagnosed. The size of the undetected group depends on quantity, quality and availability of diagnostic facilities as well as on the cultural pattern, education, social conditions and the response of the population. The surveyors were confronted with the same difficulties we encounter in interpreting official mortality statistics. The obstacles were even greater, for much less experience is available to guide us in dealing with incidences and morbidity data on cancer than we have in connection with the number of deaths recorded.

*Number of cases recognized in the study-year, in relation to the total population.

†Number of cases recognized in the study-year plus survivors of former years being treated in the study period, in relation to the total population.

The surveyors were not fully aware of the difficulties. This may account for the lack of conformity in the published reports, for the insufficient separation of resident cases from others, and for the insufficient differentiation between incidence and prevalence (= morbidity)in discussing the items under study. For the study of cancer by site in white and black, in South and North, the question, whether only cases of the study-year are considered or also survivors of cancer of former years, makes a difference in our conclusions. The surveyors did not always make clear what material they have used. Sometimes both old and new cases were lumped together and divided according to site, while cases were disregarded which had not been reported before death (compare Tables 7 and 8 on p. 108/9 with Table 3 on p. 39). Cancer cases first so classified on death certificates but not reported before death, amounted in the North to 21 per cent of the number of cases first seen during the study year, while in the South the corresponding ratio was but four per cent. It follows that, by not including these pages in Tables 7 and 8, the differences in distribution of cancer according to site might have been distorted.

For the evaluation of the accuracy of results and of completeness of cancer reporting it is of interest that in the four northern areas, in the study year, of all 10,748 certified cancer deaths 3,500, or 32 per cent were unreported prior to death, whereas in the south the corresponding figures were 1,459, 176, e.g., only 12 per cent. The latter ratio is extremely low, indicating either a level of medical work higher than in our best hospitals or, more probably, a low level and a rather unsuccessful survey. What was not recognized and reported before death remained so also at the time of death and after.

Such differences—21 versus 4, and 32 versus 12 percent—cast grave doubts on the comparability of the figures assumed to be representative for the South with those for the North and West.

I doubt whether the selected ten areas are representative of their respective three regions and of the country as a whole. From the northern region were chosen Detroit, Chicago, Pittsburgh and Philadelphia. Detroit is famous for its low cancer mortality rates, far below the average for the North. None of the other three cities belongs to the Northeast states, New York and New England, which comprise almost one-third of the northern population* and have the highest cancer mortality rates calculated for the U. S. Thus, the calculations based on the four aforementioned city areas tend to underestimate the North-specific cancer rates. On the other hand, the mortality rates calculated for the South surpass the official figures—although, at the end of the study year, it was impossible to ascertain in a considerable percentage of cases whether the subjects were alive or dead. I do not know how these cases were disposed of in the final calculations. Unfortunately we are left without link between the crude incidence rates of the earlier reports and the standardized rate for the sum of the four southern areas. In the earlier reports the crude cancer incidence rates per 100,000 were as follows: Birmingham, 139; Atlanta, 197; Dallas and Fort Worth, 255; and New Orleans 343. This is a substantial range of values. Were they real? or were they due to varying degrees of completeness of reporting and of diagnosis, or due to different age distribution of the four samples, or to a miscalculation of the total number of inhabitants? In the absence of accurate answers to these crucial questions, one cannot accept Dorn's standardized figures as representative of the South.

It has been known for some time that in colored people skin cancer is rare. It is due to a race specific resistance of the skin to actinic factors as well as to chemical carcinogens. Negroes exposed to tar very seldom develop skin cancer; but may it be that instead they develop lung or stomach cancer? Were the official mortality statistics correct, Negro males

*Except the Pacific States included in the western region.

would be less susceptible to cancer of almost all organs than white males. There are, however, strong indications that the official statistics are incorrect, although Dorn's figures seem to support them. If cases of skin cancer are excluded, according to Dorn, the ratio of the colored to the white cancer incidence per 100,000 population is .68 for males and .98 for females. In other words, the race factor is made responsible for a considerably diminished incidence of internal cancer in colored males. Although the author has lost some of his positiveness and the conviction he expressed in an earlier report, he still underestimates the underreporting in colored males. (See Table I.)

Are the here reproduced figures probable? The difference between the incidence and mortality rates is so huge that either one set or the other or both of them must substantially deviate from reality.

To compare the cancer situation of colored with whites, samples of both races have to be placed under comparable and adequate medical supervision. In one of my[11] studies where this condition has been fulfilled, (a ten-year survey, St. Elizabeth Hospital), colored had about the same cancer incidence and mortality as white Northerners and a higher mortality than white Southerners. As a whole, colored are not less susceptible to internal cancer than whites, but they have a different organ distribution of the primary tumors. Some organs are more and others less affected. This coincides with the experience of the Metropolitan Life Insurance Company.

What has been said here about the approach to the study of the race factor is equally true for the study of regional differences. Such an investigation may have a three-fold purpose. It may aim at clarification of the role of environmental factors or it may try to determine the reactivity of various stocks (within a race) to a specific environmental factor, or it may serve various purposes of public health administration.

Among whites there is less stock variation in the South than in the North. The populations of European countries from which large groups settled in the United States, differ widely as to the reported organ distribution of cancer. Some of these differences are fictitious; others are real and can be traced to dietary habits, customs, social and occupational conditions. Still other real differences can not be explained satisfactorily.

Some of the just indicated differences are found also in this country; for instance, the reversed relation between cancer of the cervix and the body of the uterus in jewish women.* Unfortunately, no reliable statistics are available for longer periods. How necessary longer periods are we learn from England where within several decades the numerical relation of deaths from cancer of the breast to those of the uterus gradually became reversed. According to my studies, organ distribution of primary tumors and the organ specific cancer incidence change more easily than the total cancer incidence. Real changes in mortality result more easily from a changed organ distribution of cancer than from a changed total incidence. None of these values is fixed, they may increase or diminish.

By surveying ten city areas (with the surrounding counties) the Public Health Service did not attempt to elucidate the problem of the specific reactions of different racial stocks. What apparently

TABLE I. Standardized rates per 100,000 population.

Cancer	Males		Females	
	white	colored	white	colored
1) incidence:				
skin	38	5	28	6(?)
other organs	182	123	218	214
incidence, all organs	220	128	246	220(?)
2) mortality, all organs	136	94	136	134

*One can not attribute this peculiarity to differences in reproductive activity. The reason is unknown.

has been tried is the determination of the reaction of whites and colored to environmental agents which act more strongly in the South than in the North. Foremost in this respect is the exposure to the sun's rays and, correspondingly, the much higher frequency of surface cancer in the South, especially among the whites.

Three questions seemed worthy of elaboration: (1) what is the total skin and lip cancer incidence among whites in South and North?; (2) whether in the South the supposedly diminished incidence of, and mortality from, internal cancer is real, especially as regards cancer of digestive and respiratory organs; and (3) if the answer to question 2 is in the affirmative, whether this low incidence represents a hereditarily determined stock characteristic or whether it is a reaction to the increased frequency of skin and lip cancer.

According to my studies[5] on the role of relevant carcinogenic factors in general and especially of dermotropic agents,[4] white southerners would be expected to have considerably diminished incidence of cancer in some—though not in all—internal organs. This would be the normal consequence of an increased frequency of skin and lip cancer. Dorn denies this relationship. Let us look first at his incidence and mortality rates.

If correct, these figures would indicate that an increased incidence of surface cancer changes but little the frequency of all internal cancers taken together; though it nevertheless and somewhat paradoxically is associated with a considerably diminished mortality from these very internal cancers. This is contradictory. According to the table, the ratio of cases to deaths in the surface cancer group is 50:5‡ (or 10:1) in the North, and 219:10§ (or 22:1) in the South. Moreover, the ratio of cases to deaths in the internal cancer groups is for men 1.2:1 in the North and 1.6:1 in the South. Similarly, for women, the two pairs of figures are 1.5:1 (North) and 2.1:1 (South). In other words, the prognosis of any cancer, be it of skin, stomach, lung, kidney, intestines, genitals, or breast, would be considerably better in the South than in the North.

I doubt the reality of these figures (cases and deaths as well), and of the proportions. Most probably, what in Dorn's report appears under the heading "incidence" is a mixture of "new" and of some "old" cases, the admixture of the latter being relatively smaller in the North than in the South. To exclude this probable source of error, in the following table the whole body of new and of old cases pooled together is being analyzed. (See Table III.)

According to these figures, southerners have an excess morbidity from cancer of all organs taken together (e); this is due to a considerable excess in surface cancer (a). Furthermore southerners have a considerable deficit in cancer of the digestive and respiratory or-

***TABLE II. Standardized rates for the white population.**

Cancer	Males		Females	
	North	South	North	South
1) Incidence:				
a) total	203	302	230	314
b) skin and lip†	31	144	19	75
c) a-b	172	158	211	239
2) Mortality:				
a) total	144	106	141	117
b) skin and lip†	3	7	2	3
c) a-b	141	99	139	114

†In Dorn's tables lip cancer is seldom separated from mouth cancer. Therefore I had to calculate the lip rates indirectly. On that account my figures may *slightly* differ from the correct values. From the point of view of cancer epidemiology lips are a part of the skin, not of the mouth. I have been propagating this view since 1936; it slowly becomes accepted.

‡50 = 31 + 19 (see Table II on incidence); 5 = 3 + 2 (see Table II on mortality.

§219 = 144 + 75; 10 = 7 + 3.

gans (b), but practically no change in the morbidity from the other groups of cancer (c and d ♂) except for the small group of "all other organs" in females (d ♀). The latter group consists of brain, bone, unspecified tumors and so on; as a whole the least reliable group. Nevertheless, this excess may be just as real as the excess in skin and lip cancer morbidity.

A population exposed to one strong carcinogenic factor, simultaneously may be exposed also to other factors, acting upon some other organs. Thus white females in the South have: (1) on account of the sun, an increased incidence of surface cancer and, therefore, a really diminished incidence of some internal cancers; (2) on account of conditions unrelated to sun exposure, an increased incidence of uterus cancer. In Dorn's figures more than two-thirds of this increase are counterbalanced by a diminished incidence of breast cancer, so that very little of the increase in genital cancer is visible when cancer of all reproductive organs is put together (see Table III sub. c.).

A careful analysis of reliable statistics enables us to trace the action of various factors, hereditary and environmental, and permits the study of interrelations between several organs. Such studies have to be carried out on man. In mice, hereditary disposition to cancer prevalence is organ-specific; in man it is not so. There exist cancer families with malignancies appearing only in the eye (retino-blastoma), or in the breast, or colon. However, they are far too rare as compared with the total frequency of cancer. On the other hand, with increasing number of pregnancies gradual changes occur in the distribution of cancer according to site, but the total incidence remains the same.[4,7] Under the influence of strong factors, up to 90 per cent of all cancers may develop in the same organ. This is the case in radium miners whose lung cancer incidence is more than 20 times increased.[6]

In all of my studies since 1922, I have found that carcinogenic factors have two effects: In cancer-disposed individuals they cause (1) at the irritated spot an increased cancer incidence, and (2) in *certain* other organs or spots a diminished incidence, partly or completely counterbalancing the aforementioned increase. The resultant of these two effects thus determines whether the *total* cancer incidence of the group increases or remains unchanged. My observations indicate that under special environmental conditions the total cancer incidence may increase to 2.5 times the usual rate. This is the case among radium miners of Joachimsthal. Under usual conditions, only a portion of the disposed group is able to react, whereas the majority remains cancer free as if they were not disposed at all. How high a percentage of disposed individuals develop cancer depends on age, sex, and quality and quantity of cancerogenic factors acting upon the group.

Since 1936 I have had occasion to broaden the basis for these conclusions by studying cancer incidence, morbidity and mortality in the U. S Army and Navy,[9,10,12] in St. Elizabeth's Hospital, by analyzing almost 100,000 female cancer deaths ,and English occupational statistics[8] and so on. I have paid special

TABLE III. Standardized prevalence* rates per 100,000.

Cancer of	Males		Females	
	North	South	North	South
a) skin and lip	54	213	33	109
b) digestive and respiratory organs	154	99	100	65
c) female genital organs and breasts			232	239
d) all other organs	119	122	35	55
e) all organs	327	434	400	468
f) internal organs	273	221	367	359

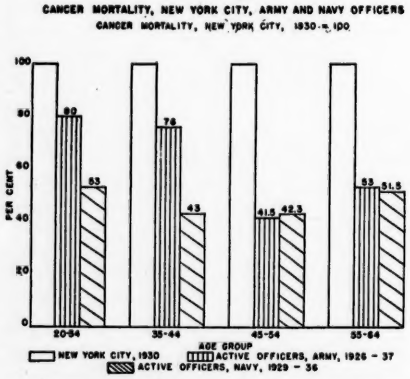
*Prevalence = Morbidity, comprising new and old cases under treatment. The figures were calculated by combining Dorn's values in Table VI, page 75, with those of Tables VII and VIII on pages 108 and 109.

attention to the problem of South and North, of white and colored, without being hampered by the many obstacles the Public Health surveyors have encountered.

The study in the Armed Forces disclosed that the peculiar organ distribution of cancer among white Southerners is influenced by the conditions present in childhood as well as later, childhood being even more important than a more advanced age. During the years of service both Southerners and Northerners are kept under uniform conditions. Nevertheless decades of service do not extinguish the differences in the organ distribution of cancer. Therefore, decisive for the distribution is either the environment during childhood or the racial stock of the southern white population. The latter assumption is improbable, as during the time of service the distribution of cancer in both the Southerners and Northerners changes toward uniformity. (See Table IV.)

All these findings bear out my conception that we might save a great many lives by provoking an easily curable skin cancer.[5] A practical demonstration of the minimum to be expected from a changed organ distribution of cancer without diminishing the total cancer incidence, is given in the age specific as well as in the standardized mortality in the Army and Navy personnel. Figure 5 exemplifies how much the mortality is cut in the group of active officers. In the Navy the reduction is even greater.

Dorn rejects my theory on the basis of the Public Health Survey, discussed above, as well as on account of experimental results obtained by Bonser and Connal.[1] These authors tarred female mice and observed the incidence of breast cancer in two experiments. As a matter of fact, in the 185 and 73 experimental mice the incidence of breast cancer (23.8 and 9.7 per cent) was smaller than in the control mice (31.3 and 42.6 per cent, respectively) and the presence of breast cancer "appeared to delay or inhibit the development of warts and consequently the onset of malignancy" (scil. tar carcinoma). However, for various reasons, these experiments neither prove nor dis-



CANCER DEATH IN THE ARMED SERVICES COMPARED WITH THE POPULATION OF NEW YORK CITY

Figure 5

The mortality for all types of cancers in New York City in 1930 is taken as 100 per cent, and the rate for Army officers and Navy officers for the period indicated is compared with this, for the age groups indicated. The differences between Army officers and Navy officers in the younger age groups are not due to any differences which are well understood or can be readily explained except for a difference in the intensity of exposure to sun and wind. After Peller and Souder, *Army Medical Bulletin.*

TABLE IV. Active personnel of the U. S. armed forces; distribution of cancer cases according to the primarily affected organ.*

Primary Organ	White Southern-born		White Northern-born		Colored	All
	18-34	35-64	18-34	35-64	18-64	
	Years of Age					
Skin and lip	71	95	28	90	3	287
Internal Organs	62	105	94	219	53	533
All cases of cancer	133	200	122	309	56	820

*Army 1926-1937 and Navy 1929-1936.

prove my point. Nor are Dorn's figures an evidence against my theory, even if we accept them at their face value and ignore their weak spots.

In cancer families with one particular type of tumor prevailing, the respective organ is more strongly disposed to cancer than any other organ. In families with retino-blastoma in children, heredity is evident.[4,14] In colon cancer families the hereditary disposition to pre-cancerous conditions, to polyposis, can be demonstrated. In these families, the hereditary factor predisposing the respective organ is so strong that the usual organ distribution of cancer is distorted. This is true for usual conditions of life. Nevertheless I assume that even in families known for their high incidence of gastro-intestinal or breast cancer, we are able to change the organ of cancer appearance. By provoking an early epithelioma of the skin we would succeed in preventing the just mentioned highly fatal cancers.

Indiscriminate and unnecessary experimentation on man is a crime, but, some experiments can be done no other way. History of medicine bears out this point. We scarcely realize that cancer surgery is still an experiment, and sometimes a costly one. It must be carried out, because nothing more promising can be done for those millions in whom cancer of the internal organs has developed. Also the experiment I have proposed belongs to the category of those which can not be replaced by observation on animals. It may be delayed on account of unwarranted opposition, but it can not indefinitely be evaded unless some new still unknown method of combating cancer should be discovered. I repeat the proposal made by me at the Cancer Symposium of the American Public Health Association in Atlantic City in 1941, namely to set up a commission of unbiased experts, to study and to discuss all the material available as well as the conclusions drawn from the materials presented, in order to plan new investigations and to bring the matter to a decision.

Perhaps the first step in the proposed experimentation should be done under the most *un*favorable conditions, namely in cancer families with a high incidence of hereditarily determined gastro-intestinal and/or breast cancers. An early provoked and easily curable immunizing skin epithelioma might give the members of these families an immunity to the fatal family taint. Those who are thus in jeopardy would have nothing to lose and everything to gain.

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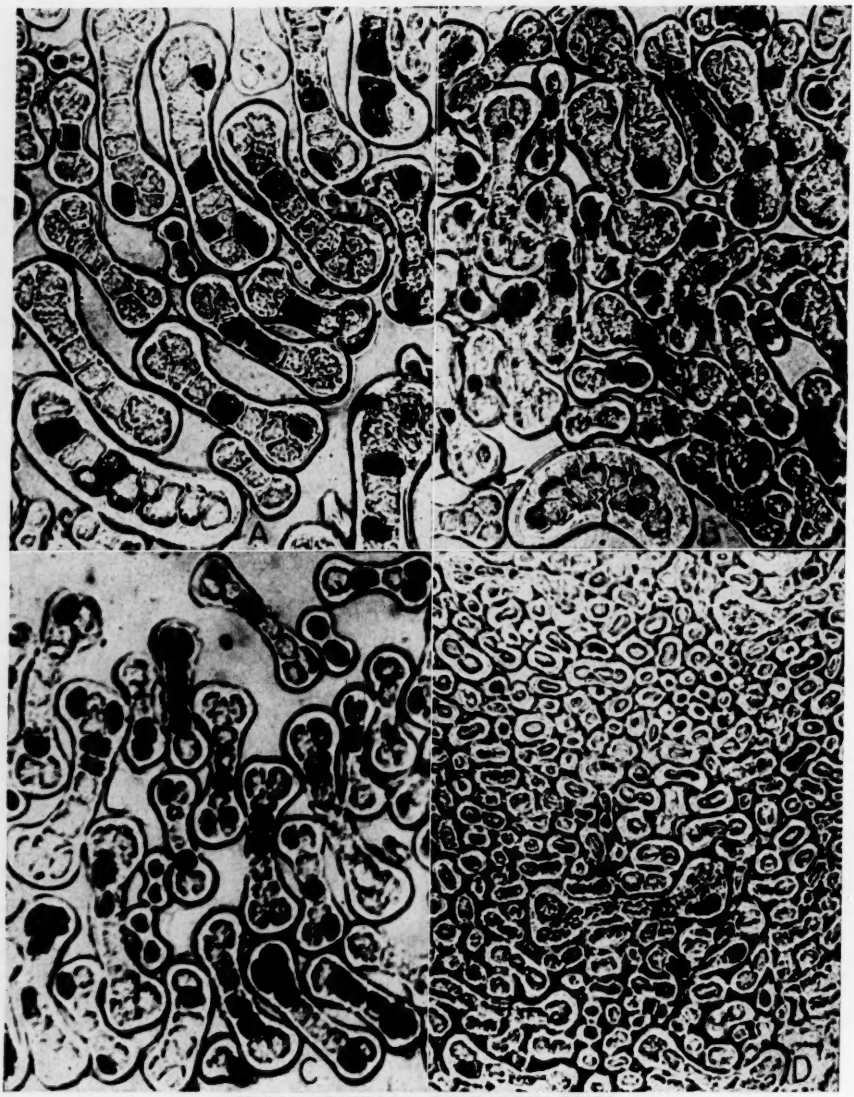

CROSS SECTIONS OF RABBIT FURS

Figure 6

Photomicrographs (approx. ×275) of cross sections of rabbit furs at the level of maximum thickness of the guard hairs, to show the character differences in these hairs. *A* shows a section taken from a homozygous normal short-haired pelt. *B* shows the same for a heterozygous short-haired pelt. *C* is a "woolly" pelt, and *D* is fur from an Angora pelt. Maximum major diameter of guard hairs is proved to be greatest in the "normal" short-haired pelts. The short-haired carriers had measurably smaller dimensions than the pure short-haired. The woolly and Angora are found to be readily separated by the microscopic measurements. The same main gene is involved in the woolly and the Angora. Selection for the Angora type of fur has built up a strain having modifiers for fine-hair characteristics. The ordinary woolly segregate is valueless as Angora rabbit wool or as short-haired rabbit fur.

A MICROSCOPIC STUDY OF COAT VARIATIONS IN WHITE NEW ZEALAND AND ANGORA RABBITS

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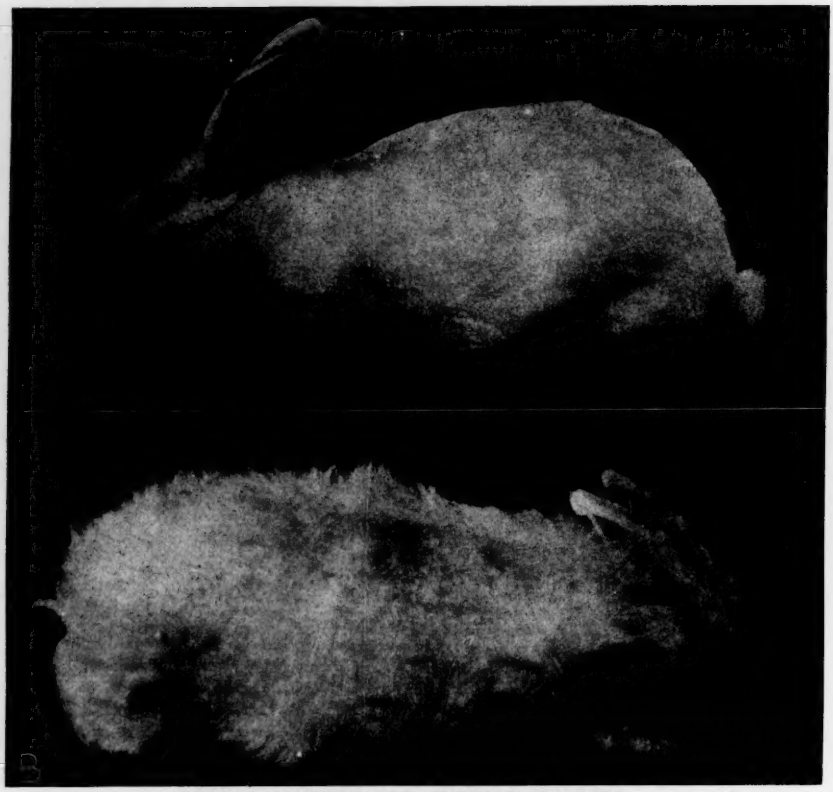
RABBITS are raised primarily for meat, pelts affording a supplementary source of income which should not be overlooked by the commercial rabbit raiser. The fur trade desires rabbit pelts which are uniform in size, texture and quality of the fur. In trying to meet these requirements, breeders are perplexed by the occasional appearance of individuals whose pelts are valueless from a fur standpoint. These are the long-haired or "woolly" individuals which are sometimes found in litters from apparently normal-haired parents. The occurrence of woolly or long-haired individuals in a rabbit colony is due to a recessive allele of the gene for short hair. The heterozygous "carrier" of "woolly" and the homozygous short-haired individuals are indistinguishable by macroscopic inspection.

One of the important problems of commercial rabbit production, therefore, is to prevent reproduction both by woolly rabbits and by the normal-coated carriers of this undesirable factor. It is a simple matter to remove those animals which possess the woolly pelts but close observations, even by expert fur handlers, have failed to find any appreciable difference between the pelts of the homozygous short-haired rabbit and that of the normal-coated heterozygous "carrier" of the "woolly" gene. The method of test-mating suspected heterozygotes to eliminate the undesirable character is in use. A direct method, such as a rapid microscopic determination, would save time and feeding costs for the commercial rabbitry.

The coats of various types of rabbits have been examined for differences in microscopic characteristics. Wucherer[14] examined the fibers from Angora, normal and carrier pelts but not from the woolly type. He contended that differences in diameter, length and density of fiber, as well as body size and length of ear enable an attentive observer to distinguish with the naked eye between short-coated heterozygotes and homozygous short-coated rabbits. In practice, however, commercial breeders have not been able to make this distinction with sufficient certainty to eliminate only the undesirable heterozygotes from the rabbitry. Salaman[12] distinguishes Angora coats of types "A" and "B" based on shapes of the fibers as seen in cross section. But since he found the "A" type to be completely dominant in short-haired animals, these features do not assist in the identification of the carriers. Consequently the present study was undertaken to find, if possible, microscopic details sufficiently clear-cut and consistent to segregate heterozygous and homozygous short-coated animals.

Microscopic examinations and measurements of rabbit hair fibers were made at different levels above the skin to detect any differences in the fiber characteristics of the three classes of pelts. Also, it was believed pertinent to compare the hair of the recessive woollys with that of the true Angora rabbit, where the woolly feature has been intensified through selective breeding to make a fiber suitable for use in rabbit wool production.

Dressed pelts from homozygous normal (1 ♀, 1 ♂), and heterozygous normal (1 ♀, 1 ♂), and a raw woolly pelt (1 ♀) were obtained from the herd of New Zealand white rabbits maintained by the U. S. Rabbit Experiment Station of the Fish and Wildlife Service at Fontana, California. The five pelts were taken from animals five to seven months of age



SHORT HAIRED AND WOOLLY RABBITS
Figure 7

The normal short-coated New Zealand white rabbit (*A*) is compared with the long-haired woolly variation (*B*). The short-haired type of coat is dominant in inheritance, and the woolly type recessive. Production of woolly rabbits through mating heterozygous carriers of the long-haired woolly gene is unfortunate for the rabbit farmer because the long-haired coat is of no commercial value.

(147 to 206 days), a period when physical maturity has been reached. These pelts were deemed to be of comparable quality by Mr. George S. Templeton, Director of the Station, for the small differences in age probably have no significance. The raw Angora pelt used was from a six months' old doe from the same source. The length and quality of this wool was typical of that usually sheared for marketing. The raw woolly pelt was taken from a mature doe. The Angora and woolly pelts used in this study were in the natural raw state, for dressing was found to cause pronounced matting and to result in the removal of many fibers. Fiber samples in all instances were taken from the mid-dorsal line at a point immediately anterior to the pelvic region.

Previous research by Salaman[12] has indicated that as a rule no noticeable differences exist between the hair shapes from various points on the rabbit pelt, such as the shoulders, flank, and hind quarters. Salaman also obtained his fiber samples from the mid-dorsal line for his studies of the inheritance of fur types and hair characters.

The present study is of an exploratory

nature to determine whether microscopic analyses are applicable to genetic problems in the production of fur animals. Although the quantity of material studied was limited, general trends were found to be so consistent, that it is believed publication of the results obtained to date would be of interest. It is planned, when conditions again permit, to amplify this investigation in order to determine the limits of individual variation by the examination of a greater number of pelts.

Description of Rabbit Types Studied

The New Zealand white rabbit (*Oryctolagus cuniculus* var.) is an albino variety with pink eyes and a wholly unpigmented (white) coat, and in America is the best known of all types of albino rabbits. To California goes the real credit for the development, perfection and dissemination of this popular breed. There are now two varieties of New Zealands, the Red and the White. During recent years the white variety especially has become a leading meat and fur producer. As with many other breeds, the name New Zealand has nothing to do with origins. In fact, as far as is known, no New Zealand rabbits have yet appeared in New Zealand.[2]

The Angora rabbit (*Oryctolagus cuniculus* var.) is a mutation in which the "Angora" or long-haired coat is a Mendelian character which is recessive with respect to the normal short coat.[3] The hair is several times as long as in wild rabbits and is softer in texture. Castle[4] has suggested that the Angora is so named because its long hair resembles that of a breed of goats supposed to have come originally from Angora, Turkey.

It is understood that the woolly, or long-haired, rabbit that occurs in occasional litters of New Zealand, Flemish and other breeds is practically the same animal as the Angora rabbit,[1] the chief difference being that the Angora rabbit has been purposely developed through careful selection and breeding for desired body and fiber characters. Such factors as feeding, condition of either parent animal, season of the year, or other environmental factors have little influence on the appearance of the character. The occurrence of woolly or long-haired individuals in the rabbit colony is due solely to inheritance, conditioned by a recessive gene. The "woolly" fur not only makes the pelts valueless for the fur trade; it lacks quality and density essential for use as Angora wool (Fig. 7).

To all outward appearance, the short-haired allele is completely dominant, the heterozygous carrier of the woolly factor being identical with the pure New Zealand rabbit mentioned above. This study shows the existence of certain microscopic hair structure differences.

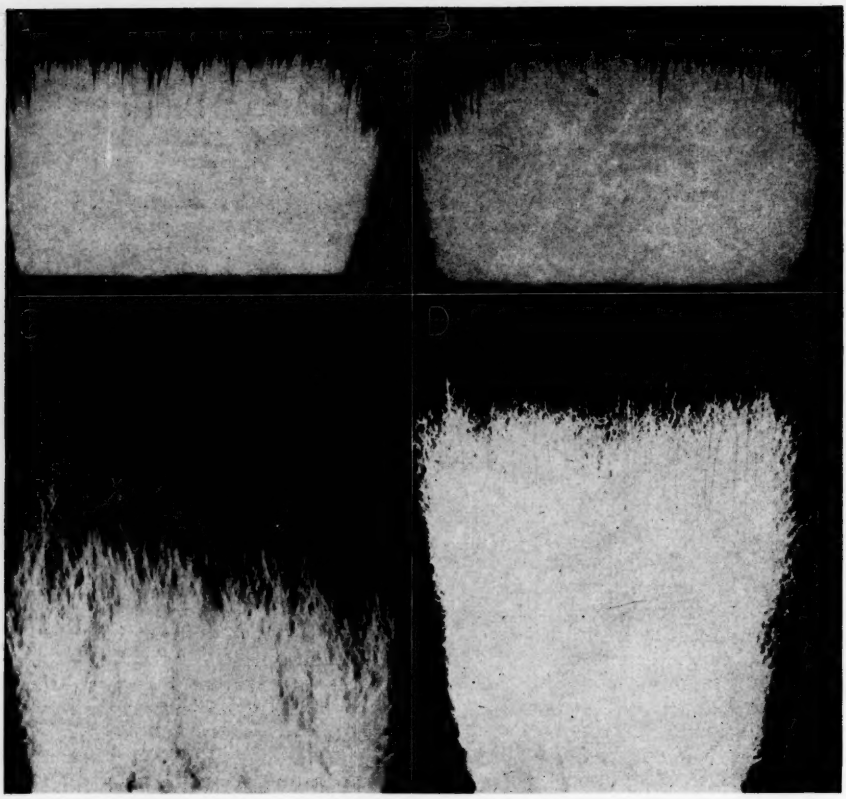
Types of Fur Fibers

As reported by Hardy and Hardy,[9] pelts from silver foxes and minks are composed of three main types of fur fibers—the underfur fibers, the regular guard hairs, and the "single" guard hairs—each of which seems to occur in varying proportions in different animals and contributes very materially to the texture and quality of the fur. In the present examination the same three types were found to exist in the domestic rabbit.

The underfur fibers of the rabbit are usually distinctly shorter and finer than the guard hairs and are crimped along most of their length. It has been pointed out by Wucherer[14] that the crimp in rabbit underfur is in one plane only, as contrasted to that of sheep in which the crimp tends to be a spiral. The underfur fibers issue from the follicle in tufts. In the present study from 8 to 25 fibers have been noted from a single follicle.

The regular guard hairs are those which do not occupy a follicle by themselves, but are found with a number of underfur fibers. Their diameters are not uniform. A widened or flattened area, within two centimeters of the tip, aids the guard hair in protecting the finer underfur fibers from abrasion.

The "single" guard hairs, issuing from a follicle alone, are less numerous than the regular guard hairs. Lengths of the two guard hair types are not identical however, "single" guard hairs often be-



LENGTH OF FIBRES
Figure 8

Sections of rabbit skin with the fur attached to show the differences in length and in texture of four types of rabbit fur: homozygous short-haired (*A*), short-haired carrier (*B*), woolly (*C*), and Angora (*D*). These sections are approximately natural size; the scale is in centimeters. Note the difference between the woolly and the Angora structure. This is a striking demonstration of selection when it is realized that the main woolly gene is the same in both types, the fineness of the Angora being due to selection of modifying factors.

ing longer than the regular guard hairs. The "single" guard hair is of a more uniform diameter from its tip to the root end. The term "guard hair," as used in this investigation includes both "single" and regular guard hairs.

Hairs in Cross Section

Microscopic examination of both guard hair and underfur cross sections usually reveals three distinct layers. The hardened outer layer of protective scales is the cuticle. It is extremely thin and in the measurements was considered a part of the cortex. The intermediate dark portion is the cortex, and the inner cavity the medulla. The cross sectional diameter of a hair may be reasonably constant, as in an underfur fiber, or it may be quite variable throughout its length, as in a guard hair. In the latter the base is usually of less diameter than the mid-section and in the rabbit the tip comes to a definite point.

The cortex of a hair contributes to its strength. The thickness of the cortex in the underfur of rabbit fur appears to be approximately constant from base to tip. In the guard hair it appears to vary somewhat with the variation in diameter along the length of the hair; at the distal end of the hair shaft the cortex and cuticle compose the entire shaft.

The medulla is filled with thin-walled

cells which present a honeycomb appearance. In the rabbit types studied these cells vary a great deal in size and shape, depending upon the level above the skin at which the section is made. Some are globular; others flattened and angular. Several shapes often may be observed in a single fiber. The cells may extend completely across the medullary section or only part way. Many are closely packed together, but other cells may be loosely arranged within the medullary cavity. Glaister[6] has commented on the large number of cells in the medulla, and upon the very broad medulla which the *Leporidae* possess.

The cross sections of hairs of seven species of the *Leporidae* family studied by Glaister[6] were almost identical in appearance. The guard hairs of these present a unique contour, being bilaterally concave. One aspect, however, which is the widened portion near the tip, is less concave than the other and possesses broad terminal portions, which we have described as being "dumb-bell shaped." In referring to both the Snowshoe hare, *Lepus a. americanus,* and to the Cottontail rabbit, *Sylvilagus floridanus mearnsii,* Mathiak[11] has also stated that the guard hairs have cross sections showing concavities.

Cross Sections

Using the improved cross-sectioning device introduced by Hardy,[7] the fiber sample was inserted into the slotted fiber holder. By nearly filling this slot with fibers, from 2,000 to 2,500 rabbit fur fibers could be cross-sectioned at one time, representing about five different microscope fields at a magnification of ×500. A coating of transparent plastic material, methyl methacrylate, was applied over the surface of the projecting fiber ends and was allowed to dry completely (three to five minutes). The fibers were then cut off flush with the metal surfaces of the instrument by the use of a sharp, single-edged safety razor blade. The superfluous plastic material was trimmed off, and the section then mounted in Canada balsam on a glass microscope slide and covered with a glass cover slip. It was found advisable to allow the slide to dry under a weight for several days before using it in the projector. Some difficulty was experienced in cutting the extremely fine Angora fibers at the desired right angle, even when new razor blades were used.

Precise measurements of fur fiber cross sections, and observations on general fiber shapes can be obtained only through the use of the microscope. Using a single tube compound microscope, the cross section images of the fibers were projected on a flat surface at a measured distance from the eyepiece so that a uniform magnification of ×500 could be obtained. The image was focused on sensitized photostat paper, and fiber measurements were made from the photomicrographs thus obtained. In taking photomicragraphs the microscope tube was rotated to a horizontal position. The source of light used was a lamp of high intensity supplemented with a diaphragm and accessory condenser lens so arranged that a fine point of intense light was centered on the cross section mounted on a glass slide. Light traveling from the prism mounted on the microscope ocular to the projection surface passed through two medium green Wratten filters to improve the definition of the cross section image. This method of procedure has been described in greater detail by Hardy and Wolf[8] in their work with wool fibers.

The fur fiber cross sections were measured with the improved bidiameter scale described by Hardy and Wolf.[8] In measuring the underfur fibers, two diameters, at right angles to each other, were noted, and the figure listed is the average of the two measurements. It was found that the guard hairs were much more irregular in shape, so more measurements were deemed necessary. All figures on guard hair measurements represent an average of four different diameters. Every fiber was measured not only for its outside diameter, but also the diameter of the medullary portion. Cross sections were made at a point approximately one centimeter from the skin level or proximal end of the hair.

Underfur fiber diameters are much smaller than those of the guard hairs, so identification of the two types presents no difficulty at this level (compare Tables I and II).

For convenience in discussing hair anatomy the terms used in the fur trade will be used to designate the three types: "normal" (homozygous short hair), "carrier" (heterozygous short hair), and "woolly."

Underfur Measurements

Careful measurements were made of cross sections of each of 500 adjacent underfur fibers of woolly, carrier, and normal New Zealand white rabbits and of fibers of the pure Angora strain. Pelts from one doe of each type and of a buck from normal and carrier rabbits were examined. A tabulation of these measurements has revealed that while slight differences are apparent in the average diameters of the underfur fibers, much more pronounced variations are to be found in their medullary diameters.

Diameters of the entire underfur fibers of normal and carrier pelts are quite similar. Fibers examined from the carrier pelt averaged only .4 micron or three per cent less than the normal fibers. Differences in the size of their respective medullae, however, were much more evident, for a variation of 2.6 microns (30 per cent) was noted.

Fiber diameters of Angora rabbit underfur fibers were found to be less than those of the woolly type, and their medullary diameters are slightly smaller.

A graph of underfur hair fineness as determined microscopically by Wucherer[14] showed that the average fiber diameters of Angora and carrier (Angora × Ermine) types occurred at 12 microns, and the normal (Ermine) at 16 microns. Our findings, illustrating a similar trend, were Angora—11.8 microns; woolly—13.0 microns; carrier—13.2 microns; and normal—13.6 microns. Expressing these medullary diameters in a different manner, in the Angora pelt the diameter of the medulla is, on the average, about 29.6 per cent of the fiber diameter; the woolly recessive, 29.2 per cent; the carrier, 45.7 per cent; and the normal pelt, 63.0 per cent.

Guard Hair Measurements

Fiber diameter measurements one centimeter from the base of guard hairs and of their respective medullae were made in the same manner as with the underfur. Since the guard hairs are much less numerous than the underfur fibers (see Table IV), it was not possible to measure such a large sample, but from 150 adjacent fibers, measurements have shown a significant correlation.

The average diameters of the guard hairs show the same trend as was demonstrated in the underfur. That is, the pure Angora strain possesses the smallest fibers of any type measured, while among the other types considered, the woolly recessive most nearly approaches this degree of fineness. The carrier

TABLE I. Comparison of average diameters (microns) of underfur 1 cm. above the skin level. 500 fibers of each pelt type. ×500.

Pelt Type		Fiber Diameter	Range	Medullary Diameter	Range
Angora		11.8	8—20	3.5	0—10
New Zealand white	woolly	13.0	3—22	3.8	0— 7
	carrier*	13.2	9—22	6.0	3— 9
	normal*	13.6	9—20	8.6	5—13

*Both sexes included.

Table II. Comparison of average diameters (microns) of guard hairs 1 cm. from base. ×500.

Pelt Type		Fiber Diameter	Range	Medullary Diameter	Range
Angora		22.3	14—40	15.8	8—36
New Zealand white	woolly	28.2	16—42	18.7	10—30
	carrier	33.8	20—48	21.4	14—26
	normal	37.1	18—48	25.1	14—30

guard hairs are intermediate in size between the woolly recessive and the normal guard hairs. The average medullary diameters of the several guard hair types show the same progressive increase in size that is indicated by measurements of the diameters of the entire fibers, i.e., including medulla, cortex and cuticle.

Since the three New Zealand white rabbit fur types did not reveal pronounced cross-sectional differences when sections were made one centimeter from the skin level, it was thought advisable to attempt the same procedure at the point of maximum width. The widened or flattened portion of the guard hair is characterized in cross section by a broad medulla with enlarged terminal portions, illustrated in Figure 6. This cross sectional dumb-bell shaped position on the fiber is not confined to a specific point along the longitudinal plane of the hair, but instead occupies a zone which is estimated to be from five to ten mm. in length. It was found that by making the cross section at a point averaging one centimeter from the guard hair tips most of the fibers exhibited this peculiar shape. Above and below this zone the cross section assumes a concave form, later becoming oval. Guard hair cross section major diameters, i.e., one measurement of the long diameter, were recorded only on the dumb-bell shaped fibers. Diameter measurements of less than 60 microns were not included in the data. One hundred guard hairs from each pelt were measured. Preliminary results of such a comparison appeared to be significant, so this phase of the study was supplemented with data on additional pelts bringing the total up to ten carrier (5 ♂, 5 ♀) and ten normal coated (5 ♂, 5 ♀) pelts (see Table III). It is evident that sexual differences in this respect are slight.

From the results given in Table III several significant differences are shown. In the normal coated pelt, the average cross-sectional measurement of the widest diameter was much greater than in any of the other types studied. Fibers from the carrier pelt are intermediate in diameter. Woolly guard hairs proved to be the smallest of the three New Zealand white rabbit pelt types in cross section. Therefore, it is apparent that smaller average fiber diameter, as well as greater fiber length, contributes to the silky texture of the woolly recessive pelt as compared to that of the normal or carrier types.

TABLE III. Comparison of the major diameters (microns) of guard hair cross sections cut approximately 1 cm. from tip. 100 fibers from each pelt. ×500.

Pelt Type		Pelts Studied Number	Sex	Major Diameter Range*		Total Average	
Angora		1	female	64	100	74.20	
New Zealand white	woolly	1	female	64	114	81.22	
	carrier	5	male	64	158	104.82	104.96
	carrier	5	female	64	156	105.11	†
	normal	5	male	76	170	124.61	124.41
	normal	5	female	78	170	124.22	

*Diameter measurements of less than 60 microns not included.

†While the numbers included in this report are not large enough to establish statistically all the differences observed, it may be noted, however, that the difference between the total averages of the heterozygote (104.96) and the homozygous normal (124.41) is 19.45 microns. Statistically, this is highly significant: $T = 16.6$, and $P < .01$.

TABLE IV. Guard hair-underfur ratios at 1 cm. from base from 1 of each type of pelt studied.

Pelt Type		Fibers Counted		Ratio	
		Underfur	Guard hair	Underfur	Guard hair
Angora		2182	23	95	1
New Zealand white	woolly	2379	72	33.5	1
	carrier	2406	31	77	1
	normal	2715	46	59	1

Proportion of Guard Hairs to Underfur Fibers

The relationship between the proportion of guard hairs to underfur fibers can be ascertained by even a casual gross examination, for the guard hair covering is very sparse. Another report[12] has stated that at the skin level, guard hairs are outnumbered by the underfur fibers from 20:1 to 70:1 in different types of rabbits.

A large number of fiber cross sections of the four pelt types under consideration were examined to make a check upon the guard hair-underfur ratios at 1 centimeter from the skin. In a mature prime pelt all guard hairs and underfur fibers can be easily differentiated at this level. The results are listed in Table IV.

These Tables (III and IV) would seem to indicate that the greater fineness of the fibers is not the only factor which contributes to the silky quality of the Angora and woolly pelts, but that a reduction in the number of guard hairs, as well as increased length of both guard hair and underfur fibers (see Table VI), may also be significant. While working with a number of Angora pelts, Salaman[12] found two distinct pelt types, one in which the underfur-guard hair ratio was 20:1, which he called type A, and another group in which the ratio increased from 50:1 to 70:1, or type B. There seems to be considerable variation between individual animals of all fur types in this respect. The Angora pelt examined in the present study more nearly approaches the "A" type in these ratios. It also appears to belong in this type because of the dumb-bell shaped cross section of the guard hairs in the thickest portion of the fibers. Salaman found this shape to be characteristic of type "A" but lacking in the type "B" Angora rabbit.

The researches of Tänzer[13] in Germany showed that the Angora pelt consisted of about 96 per cent underfur and four per cent guard hairs by actual count. However, in this study only slightly over one per cent guard hairs were counted in the Angora, three per cent in the woolly types, and about two per cent in the normal.

Number of Medullae

The cross sections of underfur fibers can always be distinguished from those of the guard hairs, not only by their smaller cross-sectional areas, but also by their respective medullae. All underfur fibers were fairly uniform in diameter throughout their entire length, round or slightly rectangular in shape, with but a single medullary cavity. The guard hair diameters, however, varied greatly in size and shape — round, oval, kidney shaped, and often elongated with enlarged ends, best described as dumb-bell shaped. The medullae, described by Hausman[10] as a discontinuous compound type, formed groups of cells in two or more columns. As many as eighteen compound medullae occurred in the dumb-bell shaped section of the fibers. All guard hairs apparently reach their maximum cross-sectional area where the fiber assumes the dumb-bell shape in cross section. Viewing the whole fiber in a longitudinal plane, this becomes the flattened portion found within two centimeters of the tip.

It will be noted from Table V that considerable variation exists in the pelt types with respect to the number of medullary cells present. This is particularly true in the woolly and Angora pelts in cross sections made near the base of the hair shaft. Salaman[12] found as many as 15 medullary cells in a single fiber of the "A" type Angora. The number of medullary cells was much greater near the distal end of the fiber where the cross sectional area is the greatest. The number of medullary cells in carrier guard hairs is intermediate between normal and woolly fibers.

Hair Length

Ten narrow strips of skin approximately two by five millimeters with the hairs attached were removed from each of the four pelt types studied. Minimum and maximum lengths of both guard hairs and underfur fibers from each skin section taken are shown in Table VI. The method of mounting the hairs for

measurement was similar to that shown in Figure 8. The white fibers, combed parallel, were placed on a black cardboard background in such a way that the narrow skin strip fitted closely against the base of the cardboard. This material was then placed between glass lantern slides held in position by a strip of friction tape around the edges.

The length of both the guard hairs and underfur fibers of the various pelt types examined again shows a distinction between the homozygous and the heterozygous short-haired samples. Those examined from the heterozygous pelt were slightly longer than in the homozygous. This is in agreement with Wucherer's findings that the average length of the hairs, by types of hair, is always a little longer in the carrier than in the normal. As stated before, Wucherer[14] has even gone so far as to say that this fact, supported by differences in hair diameter, makes it possible for the attentive observer to distinguish with the naked eye the short-coated carrier from the pure short-coated strain. The differences, however, are so slight that the validity of such a claim becomes questionable. The pure Angora fur, on the other hand, can be readily distinguished from the woolly type because both underfur and guard hair fibers of the former are much longer (see Figure 8).

Development of the long-haired character in the Angora rabbit through selective breeding is illustrated in Table VI, which shows that even the under-fur of the Angora is much longer than that of any other type studied.

Discussion

The microscopic studies of fibers from four types of short- and long-haired white rabbit pelts, yielded observations of genetic interest. Verification was obtained in this study of Castle and Forbes' report[5] that though the long or "Angora" coat in rabbits is alternative in heredity to normal or short coat, nevertheless the dominance of the normal coat is incomplete. The microscopic features of the fibers from the carrier in every case were found in the present investigation to be intermediate in character between those from the normal and from the woolly pelts. Breeding experiments of Castle and Forbes[5] were primarily concerned with guinea pigs, but also with rabbits. Wucherer[14] was also aware of this incomplete dominance between Ermine rabbits and crossbreds with Angoras.

The most pronounced microscopic difference between the fibers from the white New Zealand short-coated rabbits and the undesirable "woolly" rabbits is found in the major diameters of the widest portion of the guard hairs. It is planned, therefore, to use this measurement as a basis for future studies.

TABLE V. Comparison of numbers of guard hair medullary cells at two levels from the skin.

		Number of Medullary Cells in Cross Section					
		1 cm. from skin level			1 cm. from tip		
Pelt Type		Minimum	Maximum	Total average	Minimum	Maximum	Total average
Angora		2	8	3.00	5	10	6.86
New Zealand white	woolly	2	7	4.10	5	11	7.61
	carrier	3	5	3.88	6	14	8.66
	normal	3	6	4.88	7	18	11.55

TABLE VI. Variability of fiber lengths. 40 fiber measurements of each pelt type.

		Fiber length in millimeters					
		Guard Hairs			Underfur		
Pelt Type		Minimum	Maximum	Total average	Minimum	Maximum	Total average
Angora		76	126	90.9	59	77	68.1
New Zealand white	woolly	52	87	68.1	32	62	45.1
	carrier	33	52	40.9	23	30	26.6
	normal	34	46	38.9	22	27	24.4

Summary

Rabbit fibers were studied microscopically to detect differences in hereditary coat characters. Homozygous short-haired, heterozygous short-haired, and long-haired or "woolly" coat length variations of the domesticated white New Zealand rabbit were examined and compared with the Angora rabbit, a type which has been developed through selection for desired fiber quality. In fiber length, number of medullary cells, cross sectional diameter, and ratio of guard hairs to underfur, the hybrid or "carrier" type pelt occupied a position intermediate to the short- and long-haired coats. Hair of the Angora rabbit was found to be of lesser diameter and greater length. The most significant differentiation between the normal and hybrid short coats of the New Zealand rabbit occurred in cross sectional diameters of the guard hairs at the zone above the skin where the fiber attains its maximum diameter.

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✦

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D. C. Warren
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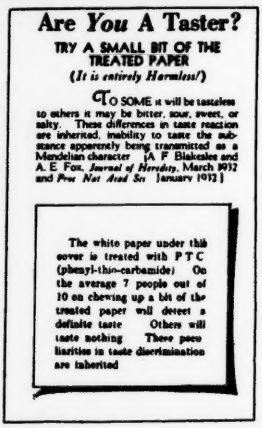
**Turkey Management*, by Stanley J. Marsden and J. Holmes Martin. Pp. 752. Interstate Press. Danville, Ill. 1944.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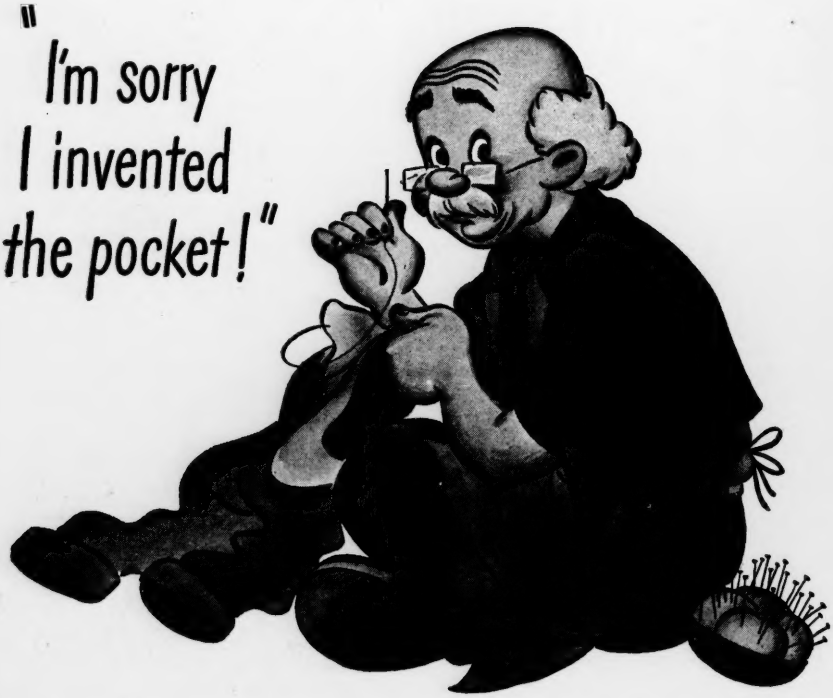

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